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There are many military situations in which small groups of individuals must live and function in confining environments for extended periods of time. The U.S. Air Force, through its contractor Hamilton Standard, has developed a model for an Advanced Base Habitat for long-term living underground. Initial manned tests of a prototype of this Advanced Base focused on engineering and life-support issues. However, having personnel living in the Habitat during the tests provided an opportunity to assess the psychological effects of the Habitat. Three tests were conducted with four crew members each; two tests of four days each, and one of seven days. Following each of the tests an interview was conducted with the crew as a group. In each test interpersonal conflict developed. This report describes how the crews dealt with the conflicts and other stressors associated with life in the Habitat. Recommendations are made for improving the Habitat and for conducting future tests.

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PREFACE

During FY87 the Systems Management and Logistics Branch, Systems Engineering Division, Food Engineering Directorate of the U.S. Army Natick Research, Development and Engineering Center (Natick) developed and tested a food service concept for feeding Air Force personnel enclosed in a self-contained and self-supporting basing mode (Advanced Base). Overall project management for the Advanced Base was retained by the U.S. Air Force Ballistic Missile Office, Norton Air Force Base, CA, through their contractors at Hamilton Standard, United Technologies. Behavioral scientists from the Science and Advanced Technology Directorate, Natick, provided support for the evaluation of the food service concept. We also took this opportunity to evaluate other psychological effects of life in the Advanced Base. Completion of this project required the cooperative efforts of many individuals. Specifically, the author would like to thank the following individuals:

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Ms. Jane Benson

Science and Advanced Technology Directorate, NRDEC

Dr. Owen Maller
Mr. James Brodeur
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"This interpersonal dissonance was of such magnitude that NASA strongly considered immediately aborting the Apollo 13 mission and returning it to earth before their interpersonal problems escalated any further."

(Cpt. D. L. Collins, 1985, p. 2)

INTRODUCTION

There are many situations, especially military situations, in which a small group of individuals must live in a confining and isolated space for an extended period of time. Normally, this type of mission can not be aborted because of interpersonal dissonance among mission-critical personnel. A great deal of research has been conducted to determine the impact of these extreme environments on human physiology, performance and psychological status. The two most intensively studied environmental situations are space flights or simulated space flights[1-5] and wintering-over in the Antarctic.[6-9]

The long missions of space flight, life in space stations and trips to the moon have motivated considerable research and provided a great deal of observational data on the effects these situations have on astronauts, such as the work by Kanas,[3] Yegerov, Gazenko and Genin,[5] and Wood and Dunivin.[4] Space flight environments subject their inhabitants to extreme confinement and isolation. There is the added impact of the threat of death just beyond the spacecraft walls. It is in this scenario that astronauts must

perform critical mission duties, some of which are highly technical requiring much premission training.

Historically, astronauts have been mostly men, but both the National Aeronautics and Space Administration (NASA) and the Soviets have recently included more women in their flight crews. These individuals are selected for high levels of physical fitness, intelligence, motivation, education, and special training and experience. Once selected, astronauts go through a long and intensive training program. The majority of the training time has been spent on acquiring specific technical skills related to completing mission related tasks. Despite this extreme selectivity and intensive training, astronauts have frequently encountered interpersonal and other psychological problems in outer space and during simulated space flights on the ground.[1,3,5,10,11] There have been reports of irritability, aberrant behavior, impaired judgement, decreased efficiency, and interpersonal hostility among crew members and between the crew and the support crew on the ground. It is clear that psychological problems during space flight can mean disaster. Therefore, it is critical to discover means to minimize the deleterious effects of these phenomena.

In the numerous studies of wintering-over in Antarctica and the Arctic, some of the same sort of problems have been observed as were found during space flights.[6,9,12,13,14,15] The individuals who are selected for these missions tend to be scientists, technicians and support personnel. As with the astronauts there

are relatively few women who participate in wintering-over. There are several differences between space flights and wintering-over. While the groups wintering-over are isolated from contact with the outside world, much of the time they are not nearly so confined. Their habitats are larger and, on occasion they go outside, albeit into an extremely hostile environment. Indeed, their environment usually consists of Spartan housing resting on 8000ft of ice with an average annual temperature of -57^{o}F (-49^{o}C) and an extreme low of -110^{o}F (-79^{o}C). One year consists of a single day and night. Under such inhospitable conditions these polar base inhabitants are exposed to 8 to 10 months of boredom, monotony and occasional danger as well as the expected isolation and confinement. As a consequence they frequently exhibit sleep disturbances, depression, irritability, hostility and possibly selected cognitive deficits.[6,8,13,14,16] These effects impact on individual and group effectiveness and, like missions in space, can have a significant adverse effect on what can be accomplished during a mission.

There are other scenarios in which individuals or groups are subjected to extreme isolation and confinement. Where research findings are available many of the same psychological effects are reported;[17-21] but see also Logie and Baddeley[22]. Against this background of research, an Advanced Base prototype Habitat was developed and tested during 1987.

Advanced Base Concept

The Advanced Base concept was proposed for an underground Habitat for the U.S. Air Force under the direction of the Ballistic Missile Office (BMO). This underground Habitat is intended to provide a safe environment in the event of an attack. The Advanced Base concept has two operating modes: a Peacetime mode and an Endurance mode. In the Peacetime mode crew members and supplies can be transferred to and from the surface. Also, power, heat rejection, air, and water can be controlled from the surface. In the Endurance mode all such capabilities have to be contained within the Habitat. Thus, all the air and water that the crew uses during the period they will inhabit the Advanced Base has to be contained in the Habitat itself. Under contract to BMO, United Technologies-Hamilton Standard constructed a preprototype Advanced Base for evaluating the nonregenerating life support systems. The primary purposes of the tests were to evaluate the equipment pertaining to life support systems and to determine overall habitability of the Habitat.

METHOD

Subjects: Subjects for these tests were six male and three female civilian volunteers from Hamilton Standard and TRW. Additionally, there was one female Air Force officer who served on one of the test crews. The average age of the males was 30yrs (range: 25-44yrs) and for the females it was 27yrs (range: 25-33yrs). Six of the crew members were married and two had prior military experience. One of the men participated in all three tests and served as group leader during the tests.

The Habitat: Figure 1 depicts the Habitat designed and built by Hamilton-Standard. It was a steel fabricated structure of dimensions 16ft wide x 120ft long x 12ft tall. The Habitat was a completely enclosed living space that provided all the necessities for survival. That is, it contained all the "air", water, and food required to sustain the crew members for the duration of the tests. Once each test began no "air", water, or food was added to the Habitat. In addition there were numerous items that contributed to the comfort of the test crews and to the ease and efficient operation of the Habitat. The living space included a kitchen, bathroom, two two-bunk sleeping compartments, an entertainment room, and an exercise room. Other functional space included a storage room (primarily food), the life support equipment room, and the "console" room, which contained a computer

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PRE-PROTOTYPE HABITAT

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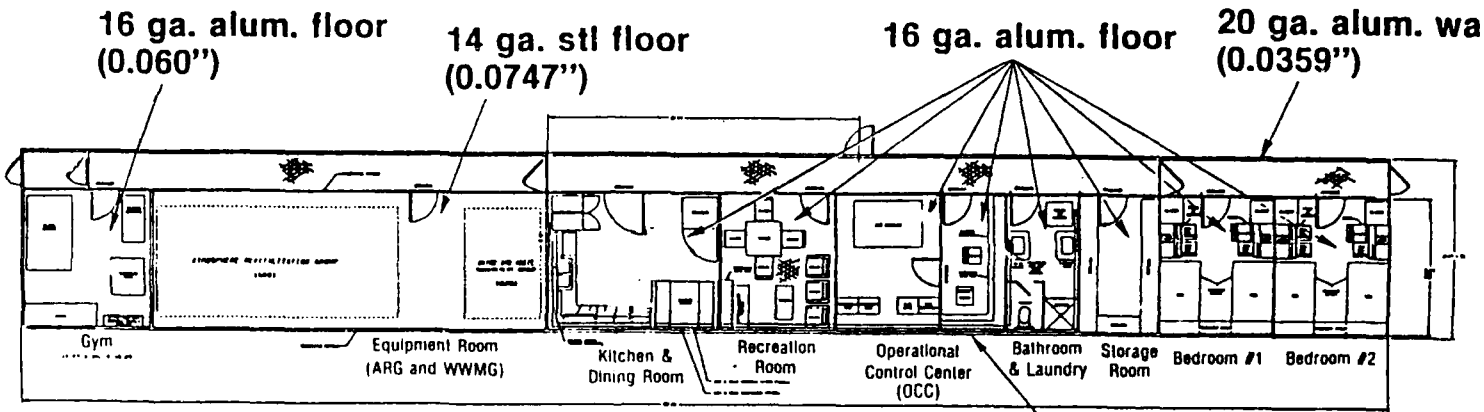

Structural materials

Note: Interior walls 26 ga. stl. clad gypsum, 1/2" thk.

Figure 1. Pre-Prototype Habitat--Hamilton Standard.

console and the life support and status display equipment.

Procedure: Four crew members participated in each of three separate tests, which were conducted during August and September, 1987. The first two tests were four days in duration while the third test was seven days long. Four men served as the crew of the first test. The crews of the second and third tests consisted of two women and two men.

Each test was treated like a short mission during which the crew members took shifts monitoring the life support equipment, communicating with test engineers on the outside, and maintaining their Habitat, including cooking their meals and keeping the Habitat clean. During their free time crew members had access to audio, video, and exercise equipment.

Following each Deep Base test, behavioral scientists from Natick interviewed the test crew. The interviews were conducted as a group, and lasted about one hour each. In two of the tests two psychologists were present during the interview. During the remaining test only one psychologist was present. These interviews went beyond questions related to the human factors analysis of the food service system. We discussed issues related to scheduling of tasks, recreation and exercise, sleeping problems, sharing of facilities, and conflict resolution. What follows is a summary of the findings from the three posttest interviews.

RESULTS

Conflict Resolution: It is inevitable, in a living arrangement such as that imposed by the Habitat, that interpersonal conflicts would develop. At least one conflict of significance arose in each test. In the first test the test crew members rapidly developed an "us vs. them" attitude toward the outside engineers, especially those who monitored the outside console and communicated directly with the inside crew members. The inside crew suggested the inclusion of a camera focussed on the outside console engineer would alleviate the problem. In subsequent tests a camera, focussed on the outside console engineer, was included. All crew members in later tests, as well as outside personnel, agreed that the camera resulted in better communication between inside and outside personnel, and eliminated the kind of antagonism that developed during the first test.

During the second test, when there were two men and two women crew members, a problem developed because one of the men did not close the bathroom door when he used it to shower or use the toilet. This embarrassed the two women, but they did not mention it to either of the men. The man who did close the door when he used the bathroom also said nothing, even though he sensed that the women were bothered by this "open-door policy". In short, the resolution of this problem was to leave it unresolved until the

exit interview, when it was discussed for the first time. It was also during the exit interview that one of the women stated that she would feel more comfortable in the bathroom if it had a lock on the inside. During the final test one of the men also left the bathroom door open when using it, but in this case the women were not much bothered and thus it never became a problem.

Finally, during the last test there was an early problem with regard to the loudness and type of music being played. Within the first 24hrs the individuals concerned discussed the problem and reached a compromise. The agreement was adhered to fairly well throughout the remaining six days of the test and there were no subsequent problems of that type reported.

Sharing the Facilities: Certainly one of the most difficult aspects of living in an enclosed space for an extended period, with people you don't know, or at best don't know well, is the challenge of sharing the limited facilities. Because the crews were made up of different people, except for the one person who participated in all tests, it is not surprising that different sets of problems arose in each test. In the first crew all members were men and, significantly, had similar interests in music, fitness, etc. They claimed not to have any difficulty sharing work responsibilities, recreation facilities, or living quarters. The two remaining crews included both men and women and some problems developed, especially regarding use of the TV/stereo facility and the bathroom. The

womens' tastes in video tapes and TV programs were not the same as the mens' and these differences caused some initial difficulty. A conflict also arose regarding the use of the bathroom. As noted under the topic of Conflict Resolution, these two conflicts were dealt with differently by the crew members.

Three other areas in which crew members interacted were work responsibilities, use of kitchen facilities and sharing sleeping quarters. Due to the strict timing of the work schedule and the lack of experience of the crews with the tasks, there was a potential for difficulties to arise with respect to the work schedule. However, just the opposite occurred. Crew members cooperated extremely well and did more than was required to accomplish whatever job had to be done. It should be noted that the work schedule was the one schedule that was adhered to during all tests. There was also some potential for difficulty in sharing the kitchen, but no problems arose. This may be accounted for by the facts that the facilities were well planned and laid out and there was plenty of food. Finally, there were no reported difficulties associated with sharing the sleeping quarters.

Feelings of Confinement: It was anticipated that feelings of confinement would emerge as a significant factor in the ability of crew members to adjust to life in the Habitat. While none of the crew members noted that they felt closed-in, other comments suggested that they had adapted to the confining aspects of the

Habitat. For example, there were several comments about windows in the Habitat. A few crew members wanted windows while others were strongly opposed to it. One crew member stated that the feeling of confinement or of being trapped would be exaggerated if windows were provided in an underground Habitat. On at least one occasion a crew member noticed that the air-lock was in use by a member of the outside crew, and this observation provided the inside crew member with a view to the outside world. He purposely averted his eyes thus avoiding sight of the area outside the Habitat. He later questioned his own behavior and explained that he did not want to be reminded of what he was missing by not being able to go outside.

The most commonly mentioned effects of being confined in the Habitat were the lack of personal items, availability of friends, freedom to go where you want, and the experience of changes in the weather. Of these potential problems, bringing more personal items into the Habitat would be the simplest to solve. Specifically mentioned were personal stereos, pillows, and photos of friends or family.

Recreation - TV/Stereo and Exercise Rooms: The TV and stereo room was popular with all crews. However, in the two mixed sex crews minor conflicts arose over choice of music and videos and the loudness of the sound system. In all cases some form of resolution was achieved. The only suggestions for improvement were requests

for more video tapes and a greater variety.

There was less consensus about, and less satisfaction with, the workout area. All of the male crew members used the gym on a daily basis. Among them the treadmill and the weights were popular. Working out with someone else was usually preferred to working out alone. The women were less enthusiastic about the gym and used it less often. They specifically requested a workout mat for aerobic type exercises. All crew members agreed that 1/ more space was needed in the gym, 2/ music in the gym would be an improvement, and 3/ the gym needed some kind of decor beyond bare walls. Posters were recommended.

Adherence to Rules: There were specific schedules for the crew members to perform work-related tasks, such as monitoring the computer console, maintaining life support systems and serving as the backup for the person at the console. There were other rules about where and what to eat and for use of the gym facilities. There was a clear pattern of adherence to the rules. All crews adhered to the work schedule very closely. There was considerable interest in accomplishing all assigned tasks and some evidence of pride in being able to solve problems together. There was considerably less adherence to the rules about meals and the gym. Meals were to be eaten in the kitchen and were supposed to be composed of only those items preselected by the crew members. However, crew members often ate their meals in the TV room or the

console area. Occasionally, a crew member would claim not to have eaten a meal; in one case it was claimed that an individual had not eaten a meal for 36hrs. Upon further questioning it was revealed that these crew members would snack intermittently to satisfy their hunger. At other times crew members "raided" the refrigerator and explained it as an expression of their "freedom" in the confinement of the Habitat. Finally, there was a rule that the gym was to be used by one person at a time. The crew virtually ignored this schedule whenever they wished. They explained simply that it was more enjoyable to workout with someone else.

Thus, there developed a consensus on which rules were important (work) and which were not (meals and exercise).

Sleeping and Sleeping Quarters: The sleeping quarters were located at one end of the Habitat some distance away from the kitchen, recreation room, and gym. Also, there was a door between the sleeping quarters and the rest of the Habitat. This distance, and the sound insulation provided by the door, made the sleeping quarters excellent for sleeping or as a place to retreat for quiet reading or writing. All crew members stated that they slept well most of the time. Occasionally, a crew member had some difficulty sleeping, but the difficulty could never be attributed directly to the sleeping quarters.

The most common complaint about the sleeping quarters was the cramped space around the bunks, especially the top bunk. Crew

members who slept on the top bunk often complained of hitting their heads on the ceiling. Also, climbing up to the top bunk in the dark sometimes presented a problem. Thus, only human factors problems were found in the sleeping quarters.

"Would You Volunteer Again?" Near the end of each interview the crew members were asked if they would volunteer again for a test in the Habitat. Almost all said "yes" right away. Two crew members were reluctant to start another test right away, but indicated that they might be willing to participate in the future. Most said they would be willing to stay in the Habitat for from five days to about two weeks in a later test, but a few individuals were willing to go indefinitely. In almost all cases estimates of how long a crew member was willing to participate in any future test was contingent on certain changes in the Habitat as discussed above.

General Comments: During the posttest interviews several comments were made that relate to points outside the prior categories.

1. The console room became the social gathering place for the Habitat, counter to the expectation that either the kitchen or the TV room would serve that function. The gathering of the crew members in the console room served to reinforce the high degree of cooperation related to work that was reported by each of the crews.

2. The issue of a final authority figure was discussed directly only with the third crew. It was the consensus that having a final authority to resolve conflicts is important and might be critical in a long-term living situation, but that the ideal situation was for problems to be resolved by the parties involved.

3. It was noted by several crew members that it was possible to tolerate unsatisfactory situations for the duration of the test because it was understood that the test would be over soon. For some crew members knowing that the test would be over, and specifically when it would be over, helped get through some difficulties in adjusting to the Habitat. These observations suggest that longer tests in which the crew members don't know exactly when the test will be over would be much more stressful and could uncover new and unanticipated personnel problems.

4. Crew members noted frequently that the computer used to monitor the equipment was too slow and produced too many false alarms. One consequence of this was that the crew started taking the alarms less seriously and may have responded more slowly and with less accuracy than is acceptable in a real-life situation.

DISCUSSION

There are several observations in the present work that parallel those made during missions in space and wintering-over in Antarctica. These common findings support the notion that a broad range of research findings can be used to aid in the development of habitats like the Advanced Base.

Compatibility among crew members and the avoidance of interpersonal conflict are among the most important factors in the psychological adjustment to living in a confining environment. Despite the brevity of the Advanced Base tests there was significant conflict in each. In the first test the crew was all male and had the greatest number of common interests. The only interpersonal conflict for this crew was between the crew and the test support engineers outside the Habitat. This sort of conflict is predictable from previous research[3,10,11] and apparently was avoided in the second and third tests by including a camera, which permitted the inside crew to see the outside crew as well as vice versa. The later crews were of mixed gender and, perhaps as a consequence, had somewhat heterogeneous interests and preferences, for example in entertainment and recreation. These mixed gender crews experienced more frequent and enduring interpersonal conflict and at least one of the conflicts was related to gender (the reaction to one crew member who did not close the bathroom door when he used it). It is impossible to determine from the present

results the relative contribution of either gender or common interests to the frequency of interpersonal conflict. However, compatibility and the avoidance of conflict are clearly important issues and should be studied further, especially with the increasing likelihood that more women will be crew members in these types of environments.

One potential means of defusing interpersonal conflict is by providing a clear authority.[11] Thus, the individual with authority can resolve conflicts early and minimize their long-term deleterious effects on crew performance. One direct study of this issue indicated that more senior authority figures, that is, those who were of higher military rank and therefore probably older, were perceived as better leaders in a confining environment.[21] The addition of rank and age aids in distinguishing the leader from the subordinates. This may have contributed to the success of the more senior authority figures in this study. In the present tests there were no strong authority figures. One individual was designated as the crew leader, but he was the same age as most other crew members and carried no other clear signs of his authority. Further, there was little attempt during the training sessions to clarify his role as the leader. Of the crew members who were asked, most agreed that having a senior authority figure would help to minimize the conflicts in the Habitat. This is consistent with the findings of other researchers[1,4] and underscores the importance of leadership in living conditions that are confining and isolated.

Schedules were agreed on before study began and were imposed on the crews in order to ensure that the limited facilities and time available to use them would accommodate all crew members. However, schedules were abrogated as it suited the crews. Thus, while the work schedule was adhered to quite closely, the schedule for use of the gym was ignored. The success of the mission was most dependent on the proper operation of the life support and monitoring equipment, which meant that the work schedule was most important. However, there is another reason that the work schedule was closely adhered to. Supervisors outside the Habitat would have known immediately had there been a lapse in performance of the work schedule. It should not be concluded that the schedules imposed failed. Indeed, they provided a framework against which the crew members could make changes that suited their requirements. In the absence of schedules the crews would have had to start from scratch to decide who did what and when. That clearly would have been an arduous and conflict-producing task.

Several times during the interviews crew members commented that the options for recreational activities took on exaggerated importance because they were so limited in number. For this reason it is critical that the recreational activities be configured optimally. Suggestions for improving both the TV/stereo and the gym facilities are presented above. These suggestions can be easily implemented, with the exception of adding space to the gym, and thus increase crew satisfaction, at least for short-term

tests. Only longer tests can reveal the effects of boredom on the satisfaction the crew members experience with the recreation facilities. In long-term tests communication with loved ones and others back home can play an important role in the adjustment and self-reported satisfaction with the living environment.[5,11] Thus, having accessible lines of communication to the outside is essential to the overall psychological well-being of the crew.

The task of organizing, equipping, and manning an isolated and confining living environment presents numerous challenges. While it is necessary to focus on the hardware, that is the physical living environment and the equipment that goes in it, it is a mistake to do that to the exclusion of psychosocial concerns. Issues related to crew adjustment in the Habitat should be engaged in the earliest phases in the development process. This aspect of the effort can be partitioned into three parts: selection of the crew, training of the crew, and defining appropriate living conditions given limitations of the crew and the mission requirements.

In a series of studies by Gunderson and associates[8,12,13] various criteria were derived that can be used to select individuals for these types of missions. Taking optimal individual performance as the goal, Gunderson used reports of peers and supervisors and clinical evaluations to derive three behavioral factors that have great predictive value. In the affective dimension, emotional control, including acceptance of authority and

calmness, was considered important by peers and supervisors. This factor fits well with the idea that leadership can play a critical role in the smooth operation of habitats like the Advanced Base. The second factor is related to task performance, specifically, industriousness, motivation, and proficiency. The third factor, likability, included evaluations for cheerfulness, consideration of others, and friendliness. These factors, as well as other relevant variables, such as experience, can be evaluated in potential crew members as a means of minimizing the chances of acceptance of individuals who are not well suited to the crew member job.

Once a crew has been selected there are significant issues related to preparing the crew for the rigors of life in the Habitat. The extent of preparation varies greatly from mininal, in preparation for wintering-over, to very extensive and lengthy for astronauts. However, the vast majority of time spent preparing astronauts for spaceflight is spent on developing technical competence in several mission areas. Very little time is spent on preparing them for the significant psychosocial challenges that occur even during relatively short missions.[4,7] The overall emphasis is on selecting the crew and then designing an environment that will sustain their biological functions primarily and their psychological functions secondarily.

In designing an Advanced Base Habitat there is understandable concern about the severe constraints imposed by limited resources available for the development effort. For example, it is not

possible to spend months, or perhaps years, to train individuals for life in a Habitat as has been the case for training astronauts. Therefore, it is critical to optimize available resources at each phase of development; crew selection, training, and the physical and psychological environment of the Habitat. With these concerns in mind, several recommendations are made in the next section.

RECOMMENDATIONS

1. Conflict Management. Even these brief tests revealed significant potential for interpersonal conflict. Further, crew members stated that the brevity of the tests made it possible to tolerate a situation which would have been difficult or impossible to tolerate for the long-term. It is obvious that unresolved, or inadequately resolved, interpersonal conflict can have a significant deleterious effect on mission completion. It is therefore recommended that specific attention be given to conflict management in the Advanced Base Habitat. This may take the form of selection of crew members who have highly developed abilities for conflict resolution, or it may require specific training in conflict management.

2. Leadership. According to the comments of the test crew that stayed in the Habitat the longest, management of conflict or situations that could lead to conflict, would be better handled with a clear authority figure present in the Habitat. In a military setting this is the norm, but because of the circumstances of these tests, it was impossible to evaluate the potentially beneficial effects of clear leadership in the Habitat. Further, it should not be assumed that the mere presence of a recognized leader will automatically minimize interpersonal conflict and result in a more efficient and effective operation. It is therefore

recommended that a clear authority figure be established for each occupation of the Habitat and that the leader(s) go through conflict management training (see recommendation 1) at the same time as other members of the crew.

3. Physical Space. The crew made several recommendations for changes in the physical space in the Habitat. One of the recommendations, adding a video camera that allowed the inside crew to see the outside crew, effectively eliminated the conflicts between those two crews that occurred in the first test. Thus, crew suggestions for improvements in the physical environment can have immediate payoffs. It is recommended that all suggestions for such changes made by crew members be noted, prioritized, and acted on to the extent that resources permit.

4. Test Crew Selection. Seven out of nine of the crew members in these tests were highly motivated civilian employees of the contractor who were specifically trained to live and work in the Habitat. Only one of the test crew members was in the military, and she was involved in the development of the project for the AirForce. It is recommended that future tests of the Advanced Base Habitat use military test crews as closely matched to those expected to be the real users as possible.

5. Test Duration. The present series of tests revealed many

opportunities for improving the Deep Base Habitat based on the comments from the test crew members. However, certain stresses associated with long term encapsulation could not be examined in these short tests. It is therefore recommended that future tests be conducted for longer periods of time, for example one month.

6. Effects of Gender. It may not be popular to draw attention to the facts relating to the effects of gender in the Habitat, but it is necessary to do so. Put simply, there is a strong suggestion that more interpersonal conflicts arose during tests with mixed gender crews than with all male crews. Numerous explanations may be offered for this finding. However, it is recommended that the effects of mixed gender crews be specifically addressed in future tests and that provisions be made for reducing the potential for conflict associated with mixing genders in the Deep Base Habitat.

FINAL COMMENT

We believe that valuable information about the long-term habitability of the Deep Base Habitat was gained from these interviews. However, the Habitat tests referred to above were originally intended as tests of the engineering aspects of the life support systems. Indeed, all of the findings reported here come from interviews that went beyond the stated mission requirements for the Natick behavioral scientists. It is important to remember that designing an environment for human habitation requires more than clear air and water, along with sufficient space and facilities to perform basic bodily functions. In order to determine what specific engineering requirements are necessary to make the Deep Base environment optimally habitable for long-term missions, it is necessary to conduct human factors analyses of all human interface components, and to assess the psychological impact of the Habitat. Failure to do this from the earliest point in development will result in cost overruns and delays in completion of the project.

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